Michael Bradley

Chemistry Honors

David Kim

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Slime and the Properties Behind It

Michael B. Bradley

Lab Report

Introduction

This lab is concerned with the properties of slime. It also aims to find what variables can be changed in order to produce varying results that be recorded and measured in order to find more information about this non-Newtonian fluid.

As previously stated, slime is a non-Newtonian fluid. This is because it exhibits properties not commonly found in normal fluids, or Newtonian fluids. A Newtonian fluid follows a basic set of rules having to do with the viscosity of a fluid. The reason why Newtonian fluids are more popular is because the common fluids air and water belong to this family. They maintain a very constant viscosity and don't change in properties when under pressure are the lack thereof. Nothing fully assumes the definition of a Newtonian fluid in its perfect state, but those that come close are considered to belong to the group. The slime belongs to the family of non-Newtonian fluids. This means that its viscosity changes under certain conditions and doesn't always remain constant. Specifically, slime's viscosity changes when it is agitated. For example, if the slime is stirred quickly and for a period of time, it will thicken and become more viscous, while water would remain the same thickness, no matter how long it is stirred.

Shear stress is a topic that also has to do with the slime belonging to the non-Newtonian family. The shear stress properties of the slime allow the slime to change viscosity when force is applied to it. As discussed before, the slime thickens when it is agitated. The slime's stress is higher than most other fluids, and this is what allows it to hold itself together and not flow around an object such as hands.

Polymers are collections of monomers strung together in a series. They are commonly found both in nature and in the industrial world. The glue used in this lab is made of polyvinyl acetate, composed of the compound with the formula, $(C_4H_6O_2)_n$. This polymer is commonly used for binding two substances together. Not on an electron level, but enough to be used as an arts and crafts standard. In this lab we add a borax solution to the polyvinyl acetate in order to cause its polymers to begin

cross-linking with each other.

Cross-linking is the process by which individual polymers bond with each other. This results in properties such as increased hardness, decreased flexibility, as well as a higher melting and boiling point. It is commonly used during the synthesis of rubbers. The cross-linked polymers allow the once liquid to solidify. The same process happens with the slime. The slime used to be a fluid-like glue, but became a solid-like goo once borax solution began the process of cross-linking.

Polyvinyl acetate is the glue being used for this lab. It has properties that are going to be taken advantage of. In this case, the process of cross-linking that occurs when borax solution is added to it. The polyvinyl acetate clumps together and becomes a solid. Once it is a solid, the new properties of it are tested. These measurements are as follows: bouncing ability, stretching ability at quick pace, stretching ability at slow pace, squishing information, sitting information, and hanging ability. The data is analyzed and printed below.

Purpose

The objective of this lab is to demonstrate the ability to control the properties of slime by altering the ingredients that are added to the solution when integrating and synthesizing the slime. Slime is an interesting material. It is a non-Newtonian fluid which is created with polyvinyl acetate $(C_4H_6O_2)_n$ and borax $Na_2B_4O_7 + 10\mathrm{H}_2O$. The polymers of polyvinyl acetate cross-link together to form a substance with solid-like properties.

The amount of borax has an effect on the stiffness of the slime, as well as other properties. By controlling the amount of borax put into each slime solution, the weight of the properties of the slime can be inherently controlled. The data collected from this lab helps to better understand the connection between the borax ratio and the attributes of the resulting slime. The slime is created by mixing together the correct ingredients, measured through various methods, and disposed of.

The expected formula for the behavior of the slime as borax is added is $f_{[0,1]}(x) = ax + b$, *f(x)* being the abundance of the solid properties of the slime, *x* being the percentage of borax that makes up the solution, *a* being the rate at which the properties are altered, and *b* being the initial starting point.

An altered of this formula may be required though:

$$f_{[0,1]}(x) \begin{cases} ax^2 + bx + c & x \leq n \\ d & x > n \end{cases}$$

The variables have similar purposes as before.

The individual properties of the slime may have to require each of their own equations in order to better express them. But the equation discussed here is likely to be the mean of the other information and a summary of the change of the properties as quantity borax is increased.

Hypothesis

If twice as much borax is added to the slime solution then the slime will take on more solid-like properties because the extra borax will cause greater amounts of cross-linking to occur within the polyvinyl acetate.

The properties that become more prominent: bouncing ability, stretching time, squishing difficulty, sitting information, and hanging time. Bouncing ability will increase for nearly the entire range of borax amounts. Stretching time will only increase until a certain point and then reduce, following a quadratic path. Squishing difficulty will increase as borax increases for the entire range. Sitting information will be predictable for the entire range. And, hanging time will increase to a a certain but instead of being linear, will follow a quadratic path.

Materials

- 1 plastic cup
  - To hold the solution while it is in the process of cross-linking
  - Will be disposed of once slime has finished cross-linking
- 25g of white glue
  - Contains the polyvinyl acetate that is necessary in order to form the rubbery slime substance due to its property to cross-link in the presence of borax
- 16ml of borax solution (4%)
  - To cause the polyvinyl acetate to cross-link and form a solid-like substance
- 1 plastic spoon
  - To stir, agitate, and homogenize the solution before it has cross-linked to much to be stirred anymore
- 1 drop of food coloring
  - To add color to the slime for aesthetic purposes
- tap water
  - Tap water used for cleaning slime and hands after synthesis.

Procedure

1. Put on safety goggles
2. Pour 25g of white glue into plastic cup
3. Add drop of food coloring to plastic cup
4. Use plastic spoon to knead and homogenize solution
5. Repeat this process 4 times
6. Add 4ml of borax solution to plastic cup
7. Use plastic spoon to knead and homogenize solution
8. Take the slime out of plastic cup with hands and knead
9. Wash the slime and hands under tap for no longer than 30 seconds
10. Knead the slime with hands until both the slime and hands are no longer dripping
11. Perform experiments with finished the slime
12. Record data about experiments
13. Dispose of the slime as directed by teacher

Data, Results, and Observations

Table: Slime Sample Comparison

Attribute (amount of borax)	**4ml**	**16ml**
Bouncing (drop height of 2')	6”	7 ½”
Stretching Fast (distance from length of slime until division)	6”	4”
Stretching Slow (distance from length of slime until division)	N/A (too large to measure)	8”
Squishing (diameter from to)	2” to 4”	2” to 3”
Sitting (time to bind to surface)	5 seconds	30 seconds
Hanging (applied to underside for 15 seconds) (until fall)	47 seconds	3 seconds

Qualitative Observations

Bouncing

The 4ml slime bounces with a style close to that of a main brand bouncy ball. It maintains its shape after impacting with the table. This allows it to repel itself back away from the table.

The 16ml slime bounces in the same way as the 4ml slime, except that it is stiffer and therefore tends to bounce higher.

Stretching

The 4ml slime could be stretched to very long lengths with general ease. It obviously loss strength the farther it was stretched but it never broke when stretched slowly. When stretched at a quicker rate, the body of the slime could not keep up with the increased width and eventually the body split.

The 16ml slime exhibited interesting properties as it began to tear before it eventually split. The tears spread and grew more prominent until the substance tore in two. The 16ml slime felt dryer and it had less fluid like properties. It had difficulty conforming to the new shape it required after being

pulled into a longer strand than normal.

Squishing

After cross-linking, both of the slime substances are resistant to squishing. The 16ml slime is more resistant than the 4ml slime and requires greater force to achieve the same measurements as the 4ml slime.

Sitting

Although both of the substances eventually being to bind to the surface of the tables in the lab, the 4ml slime with the more liquid-like properties is binding quicker. The 16ml slime on the other hand takes a longer amount of time to achieve the same binding amount. The 4ml slime also holds tighter to the table's face while the 16ml slime releases with very little pressure.

Hanging

The 4ml slime was applied to the underside of the table for 15 seconds and after stretching for approximately 30 seconds, it began to lose its grip on the table and fall away. The slime was easy to apply and was secure directly after being applied for the allocated time. The outside edge of the slime peeled off slowly, but as more and more area lost its grip, the area peeling away grew exponentially up until the point of release.

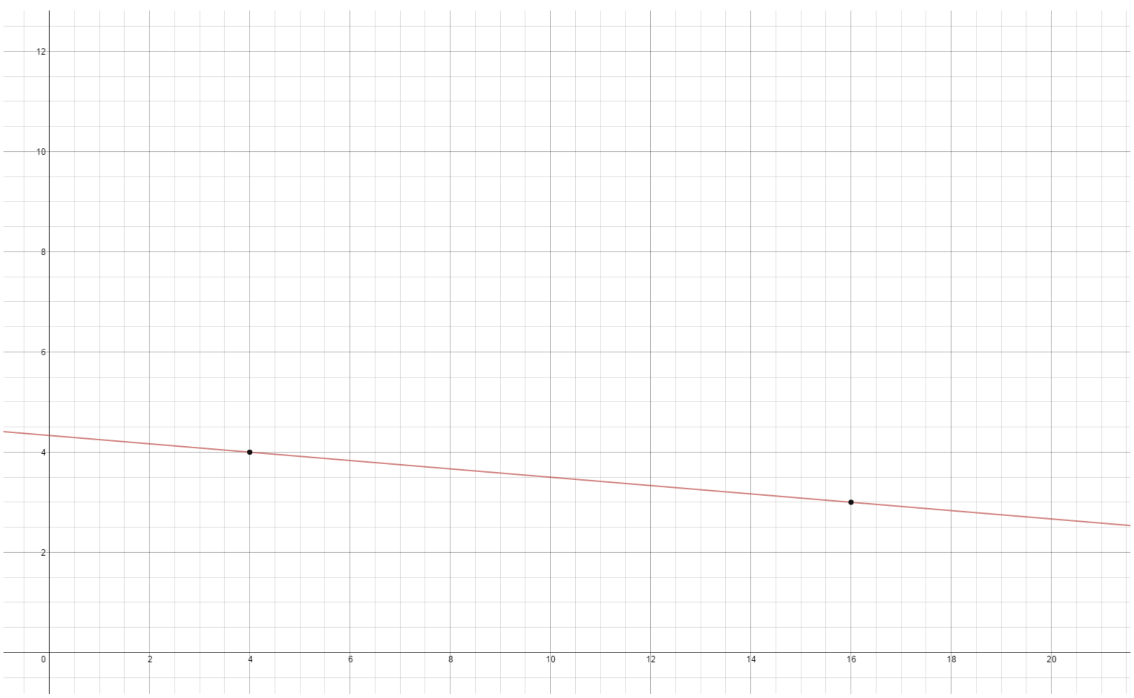
The 16ml slime acted in this experiment how a moist object or rubber might react. After being applied to the underside of the table, it took mere seconds for the entire mass to fall away. It appeared that one of the factors that contributed to this occurring was the observation that the slime was not stretching by the force of gravity, reducing some of the weight that pulled it downwards. The slime also did very little when it came to spreading its area across the material. It was only able approximately double its surface area exposed to the table, which wasn't enough to compare with the 4ml slime.

Discussion / Analysis / Calculations

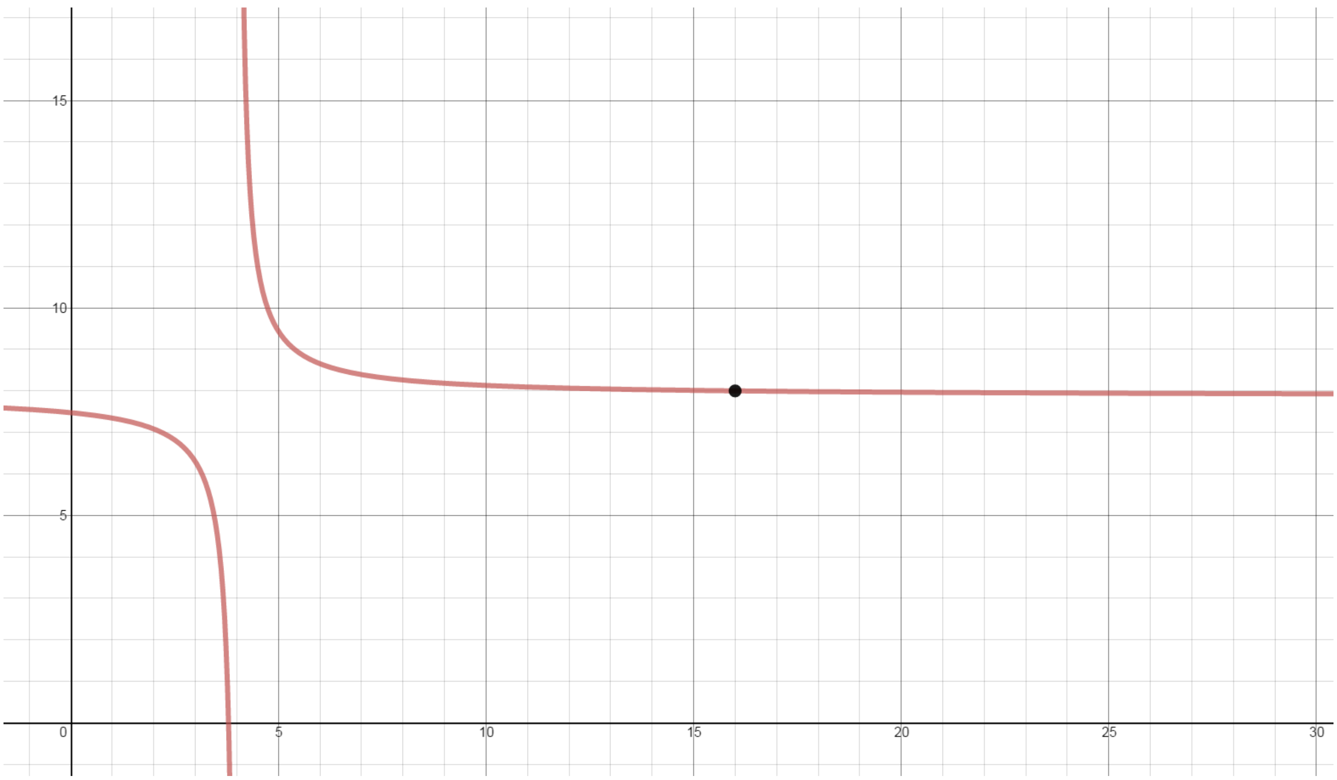
As the borax of the slime solution was increased, trends are seen in the data. It is difficult to choose whether or not either equation from the purpose is the correct one to use. The table that follows shows the information about slime and how they compared when they were being squished:

4ml slime	16ml slime
2” to 4” diameter	2” to 3” diameter

This information accurately shows that there is a connection between the amount of borax being put in the solution and the resistance of the slime to spread out when a force is applied to it. This means that the materials strength has increased. Likely this has been caused by an increased amount of cross-linking that is occurring between the polymers of the polyvinyl acetate. The borax is able to come into contact with polymers, making the solution much thicker than it normally would have been. This graph describes the trend if mapped on an $f_{[0,1]}(x) = -\frac{1}{12}x + \frac{13}{3}$ line.



The same trend can be seen when the data concerning the stretching of the substance is analyzed. As it is commonly known, Newtonian fluids are able to be stretched into extremely long lengths, as long as all the surfaces are supported. This means that in a zero gravity space, fluids could be pulled into a length only limited by their surface tension. The slime does not follow this rule, as its non-Newtonian properties cause it to resist stretching with a much larger weight than per the normal expected amount. This graph $f_{[0,1]}(x) \approx \frac{1}{x-4} + 3/2$ demonstrates the trend.



Conclusion

This experiment is meant to help the scientific community to better realize the properties that the non-Newtonian fluid slime has. My hypothesis stands correct as the data demonstrates that as borax is added to the solution, the solution becomes more solid-like. This is because when inspecting data about attributes such as stretching, squishing, and hanging, the information showed that when comparing the 4ml solution and 16ml solution the 16ml solution often expressed solid-like properties such as not being able to stretch as far, inability to squish into disc, and a shorter period of time for the slime to hang underneath the lab table.

Overall the averaged information would suggest this lab was successful in what it attempted to accomplish. One of the major issues though, is the lack of data sources being used. The information would have been much more meaningful if their had been a larger set of slime solutions synthesized. The next issue that the lab posed was not specifying the values to use when recording data. Although my data accounted for this problem. The lab should provide information such as how long to apply the slime to the underside of the table or with what force should be applied to the slime when squishing and for how long. This would allow for multiple lab executions to be able to more easily compare data.

Another aspect of the lab that could be improved on is the precision of the ingredient additions. Not as a human error, but as the lab needing the information on how to account for precision problems that will inevitably be encountered when attempting to synthesize slime.

This lab has taught me about polymers and the effect that cross-linking can have on a substance that appears to be a Newtonian fluid but is really not. Concerning the lab experience, I learned how to produce slime and convert straight polyvinyl acetate into a rubbery substance. This could help me in a later lab in which I might need to use the properties of cross-linking in order to strengthen substances composed of many polymers.

Bibliography

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